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DEFOLIATION OF CHERRY TREES IN RELATION TO WINTER INJURY

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W. O. GLOYER AND HUGH GLASGOW

ABSTRACT

In 1928, the Montmorency cherry trees of western New York showed great variation in the amount of defoliation caused either by a physiological disease known as yellow-leaf or by the leaf-spot fungus (*Coccomyces hiemalis*). In some orchards a tree would show 50 per cent defoliation, while a neighboring tree would be free from this disorder. Under similar conditions the most vigorous trees showed the least defoliation.

Applications of lime-sulfur solution, with or without lead arsenate, were made in various orchards to ascertain the time when leaf infection by the fungus *C. hiemalis* could be prevented. All orchards were not infected on the same date. Apparently there were two major periods of infection. The first occurred during the rains of June 4 to 7, while the second took place during the heavy rain of June 14. In most orchards an application of a fungicide made prior to June 14 controlled the leaf-spot. In the other orchards where early infection took place an application made June 2 or 3, which was 10 days after petal fall, controlled the fungus. The experience of 1928 and other years has shown that the orchardist cannot omit the application of a fungicide 10 days after petal fall without incurring risk of defoliation of the cherry trees by the leaf-spot fungus.

Where timely applications of fungicides were made so that leaf-spot was not a factor, there was a close relationship between defoliation due to yellow-leaf and winter injury of the roots. In other orchards it was impossible to classify distinctly leaf-spot and yellow-leaf, since they were found more or less associated on the same tree. Whether or not defoliation affects the crop of the following year depends upon the time that the leaves fall. Since the buds of the cherry are formed comparatively early in the season, the later in the season that defoliation takes place the less will be the injury to the following crop. In some years winter killing of the branches may take place where trees have an insufficient amount of stored food material. It is believed that in 1917-18 the killing was due to this cause. In 1928, winter injury of the roots was associated with the epiphytotic of leaf-spot.

Sweet and sour cherry trees died at various periods during the year. Some of these were injured during the open and mild winter of 1927-28, while in other cases the injury could be traced back to 1922-23.

Trees injured in 1927-28 may linger for several years before they either die or outgrow the injury. In some cases proper pruning with applications of a readily available nitrogenous fertilizer, such as sodium nitrate, might be tried to save the trees. On old, upright-growing trees excessive pruning should be avoided as it may have a tendency to induce winter injury.

INTRODUCTION

In the cherry-growing districts of western New York, orchardists in the past have had to contend with various insects and fungous diseases which have appeared and disappeared in periodic cycles. Periods have been observed in which the brown-rot, or leaf-spot (9, 10)[1] or cherry fruit fly (3) has been the predominant factor. In recent years many orchardists have felt that the fungous diseases were less important than the injury caused by the cherry maggot (*Rhagoletis cingulata* and *R. fausta*).

After the experience of 1926 and 1927 in which the fungous diseases, tho present, were of secondary importance, some orchardists decided to make only the sprays necessary for the control of the cherry fruit fly. Hence, in 1928 there was much variation in the number and the timeliness of the applications of spray.

The present trend in the cherry industry is to reduce the cost of spraying operations to a minimum. It appears, however, that growers are not justified in ignoring some of the applications which are designed for the control of fungous diseases. In order to ascertain the basis of the grower's attitude, experiments were undertaken in commercial orchards to note which applications were of the greatest importance in 1928. Hence a number of orchards were given certain of the recommended applications, while in others various sprays were omitted. It was anticipated that the results would throw most light on the control of the cherry fruit fly, but to our surprise considerable information was obtained on the epiphytotic of the leaf-spot fungus (*Coccomyces hiemalis*) on the Montmorency cherry.

It is impossible to review here the results of all investigations on the shot-hole fungus carried on in this state since 1886 when Arthur (1) called attention to this fungus as being of economic importance

[1]Refers to Literature Cited, p. 27.

on the plum. It is believed that he first found and figured the perfect stage of the fungus which Higgins (4) later placed in the genus *Coccomyces*. Arthur sensed the significance of the perfect stage when he recommended that the leaves should be plowed under in May before the ascospores had matured.

DEFOLIATION OF CHERRY TREES IN 1928

After the heavy rain of June 19, the yellowing and dropping of leaves of the Montmorency cherry trees first became noticeable in orchards not sprayed under our direction. A few leaves, which were still green or slightly tinged with yellow, were found on the ground,

FIG. 1.—DEGREE OF DEFOLIATION ON VIGOROUS AND ON NON-VIGOROUS MONTMORENCY TREES.
There was 2 per cent defoliation on the former and 60 per cent on the latter when photographed on July 14.

while numerous leaves on the trees were badly spotted and turning yellow. The yellowing increased so that on July 3 it was at its maximum. Defoliation became general and after the rain of July 9 most of the yellow leaves had fallen to the ground.

At the time of maximum yellowing of the leaves it was common to find entire orchards that showed a yellow cast evenly distributed thruout the tree. In a few orchards it appeared at a distance as tho a horizontal line was drawn about one-fifth of the way from the top

of the tree which separated the golden foliage from the dark green leaves below. Apparently, the owners had sprayed the trees from the sprayer and failed to reach the tops. The early infected trees lost their yellow cast entirely by July 15 and instead assumed a reddish tinge due to the red cherries showing thru the scant foliage. Such trees showed great variation in the time of the maturing of the fruit. Under normal conditions the fruit matured uniformly so that it was ready for harvest during the week of July 16. The outermost fruit of defoliated trees was undersize and red in color, while on the innermost branches the cherries were still green so that harvesting was delayed. The grower had the alternative of picking the fruit a second time or making a light application of an emergency spray to check a possible infection of the brown-rot fungus.

It was difficult for orchardists to understand why some trees were badly defoliated, while a neighboring one, as shown in Fig. 1, was normal. As all the trees received similar sprays, cultivation, etc., it was evident to the writers that the vigor and the previous history of the tree played some part in the amount of defoliation that took place.

CAUSES OF DEFOLIATION

In endeavoring to ascertain the causes of the falling of cherry leaves it was evident that all of them did not drop from the same cause. In some cases it was certain that defoliation was due either to a fungous infection or to a physiological cause. To clarify the discussion it appears advisable to enumerate and describe briefly the various factors that caused defoliation of sour cherry trees in 1928.

SPRAY INJURY

Under some conditions of temperature and high relative humidity, it is possible to obtain leaf injury with some fungicides or insecticides that are not generally recommended for cherries. As there was more yellowing and defoliation on check and unsprayed trees, the factor of spray injury does not enter into this discussion.

YELLOW-LEAF

The yellow-leaf of the cherry was first described by Stewart (10) as a non-parasitic disease. Its distinguishing characteristic is the lack of lesions on the surface of the leaf as shown in Fig. 2. Similar leaves were common in well-sprayed orchards in 1928. Some of the leaves were entirely devoid of chlorophyll, while others showed more or less mixture of green and yellow. Yellow-leaf was most abundant on the non-vigorous trees which indicated the close relation between defoliation and the amount of available nutrients present.

In some years the occurrence of yellow-leaf may be due to lack of sufficient moisture in the soil. In 1928 Montmorency trees were grown in large wooden boxes in the greenhouse until they had made a growth of about 18 inches. They were placed outside during the hot spring weather and sparingly watered so as to simulate drought conditions. The oldest leaves were the first to yellow and drop and this continued until the distal leaves only remained. In 1928 there were ample rains so that yellow-leaf could not be attributed to lack of moisture.

Following winter injury there may be a yellowing and falling of the leaves which may be associated with more or less wilting of the foliage. Such yellowing is accompanied by a reddish tinge and can be distinguished from that caused by other physiological factors producing true yellow-leaf. A leaf scorch described by Stewart (6, 7) may also be attributed to weather conditions. In this case the leaves turned brown and remained attached to the tree for some time before finally falling.

LEAF-SPOT

The fungus *Coccomyces hiemalis* produces a yellowing of the cherry leaf which is distinguishable from the true yellow-leaf in that lesions are formed varying from the size of a pin point to a quarter of an inch in diameter. As shown in Fig. 2, numerous small spots may be present, and in some cases but a single lesion may be produced. When the infection takes place on the growing, expanding blade there is a tendency for the lesion to dry, shrink, and fall away from the healthy tissue so as to produce a shot-hole effect. On the older leaves the shot-hole effect is lacking, and instead, the leaf turns yellow and falls from the tree. In 1928, in untimely sprayed orchards, the leaf-spot was the primary cause of defoliation on non-vigorous trees with more or less complication due to yellow-leaf.

FIG. 2.—YELLOW-LEAF AND LEAF-SPOT ON MONTMORENCY.

This fungus also produced lesions on the fruit and stems of cherry as shown in Figs. 3 and 4. On the yellow-green fruit of the unsprayed Morello, sunken lesions varying from a pin point to a sixteenth of an inch in diameter were found. As the fruit ripened, these spots were masked, altho they could be detected on close examination. The brownish to reddish colored lesions superficially resembled the punctures made by the cherry fruit fly. They can be distinguished by examination, since the lesion produced by the fungus is devoid of a puncture.

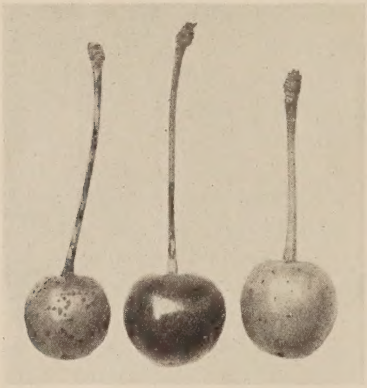

FIG. 3.—LESIONS ON THE FRUIT AND STEMS OF MORELLO PRODUCED BY THE LEAF-SPOT FUNGUS, *Coccomyces hiemalis*.

Stewart (6) first described the lesions produced by this fungus on the stems of Morello cherry and the writers found it present on Montmorency and Early Richmond where it was not of commercial importance even in unsprayed orchards. The reddish to brownish lesions closely resemble a similar injury produced by excessive use of lead arsenate (2). They are of various sizes and may extend for a considerable length and finally constrict the stem. The acervuli (spore-bearing surfaces) of the fungus with their spores were easily identified on the newly formed lesions.

The defoliation observed during a period of years seems to indicate a relationship between the rainfall and the infection of the leaf-spot fungus (*C. hiemalis*). According to Stewart (9, 10), the leaf-spot fungus caused defoliation in 1916 and 1917. In the former case it was considered the most destructive season for cherries in 20 years. In consulting the weather reports at the Station for those years it appears that they are almost a duplication of 1928. In those years it appeared that the rains prevented the timely applications of the sprays.

At the opening of the spring of 1928 the seasonal conditions were about normal. Montmorency was in full bloom May 17 and at

Geneva the petal fall took place about May 22. In orchards along Lake Ontario these periods were about one week later. The vegetative growth was delayed due to cool, continuous rains during June. There were 6.99 inches of rainfall and on only nine days of the month rain did not fall. As rainfall played an important part in the amount of leaf-spot present, it is of interest to note the precipitation during the month of June as shown in Table 1.

TABLE 1.—AMOUNT OF RAINFALL AT GENEVA DURING THE MONTH OF JUNE FOR 1916, 1917, AND 1928 WHEN LEAF-SPOT WAS PREVALENT.

DAY	RAIN IN INCHES		
	1916	1917	1928
1	——	0.09	——
2	0.04	——	0.15
3	1.25*	trace	——
4	0.04	——	0.12
5	0.38	0.67	10.53†
6	0.08	0.06	0.78
7	0.11	1.24*	0.03
8	0.32	0.15	——
9	0.06	——	0.19
10	trace	1.05*	trace
11	0.63	0.08	——
12	——	——	——
13	——	——	——
14	——	——	1.56†
15	0.19*	0.04	——
16	0.64	0.16	——
17	0.88	——	——
18	0.20	0.19	0.20
19	0.42	0.50*	0.91†
20	0.11	0.66	——
21	0.10	——	0.35
22	——	——	0.12
23	——	trace	0.05
24	trace	0.59	0.59
25	0.38	trace	0.56
26	——	0.21	0.19
27	——	0.77	0.01
28	——	——	——
29	——	0.61	0.32
30	——	——	0.33
Total	5.83	7.07	6.99

*Dates favorable for infection in 1916 and 1917.
†Dates on which infection took place in 1928.

During the month of June spraying operations were very irregular. Many growers omitted the application after petal fall. A few compromised between that spray and the one usually applied 10 days after petal fall and made an application prior to June 1 (at Geneva).

Such a spray gave good leaf-spot control in some orchards and held the disease until the applications were made for cherry fruit fly. It will be observed from Table 1 that the rains prevented the timely applications 10 days after petal fall, which was about June 2 to 4. The rains postponed operations in 1928 until June 7. From that time until June 14 the orchards were sprayed intermittently between showers. It appears that between June 2 and June 14 there were two periods favorable for spore germination and infection. The first took place on June 5 and 6, while the second occurred during the rain of June 14. The sprayings made in various orchards verified the fact that due to location, exposure, air drainage, etc., infection did not take place uniformly on the same date in all orchards. Another wave of infection took place between June 19 and 27, but this was mostly held in check by the timely spraying at the first maggot application. The last infection on the younger leaves was associated with the shot-hole type of lesions.

RESULTS FROM SPRAYING TEST ORCHARDS

Montmorency orchards, varying in age from 15 to 25 years, were given the standard applications of lime-sulfur solution at the rate of 2½ gallons to 100 gallons of water. For insect control 2½ to 3 pounds of lead arsenate were added to 100 gallons of the fungicide. Where pre-blossom applications of the fungicide were applied it appears that no difference could be noted in the amount of leaf-spot when compared to check trees. Hence it threw no light on the subject of cherry leaf-spot control. In commercial orchards the first application for the control of the cherry fruit fly was made about June 12 to 15, while the second was recommended for June 25.

A brief summary follows of the various orchards sprayed at different times and of the amount of leaf-spot recorded on July 3 when it was at its maximum.

Orchard 1.—This is the Station orchard and had been given the petal spray on May 25 and that for the fruit fly on June 12. The trees made a good growth and neither leaf-spot nor yellow-leaf were present.

Orchard 2.—This orchard received both of the sprays for the cherry fruit fly on June 12 and 28 and showed freedom from leaf-spot and yellow-leaf.

Orchard 3.—This orchard produced a good crop in 1927 and was one of the few defoliated at the end of that year by the leaf-spot organism.

The dead leaves were not plowed under and the orchard received no cultivation in 1928, having been allowed to become overgrown with weeds. This orchard received but one application of spray on June 12 to control the cherry fruit fly. On July 3 no leaf-spot was in evidence, altho check trees showed at least 15 per cent of leaf-spot. The fruit showed uniformity in size and ripening, and one of the largest crops was harvested. The orchard, however, showed an average of about 0.5 per cent of yellow-leaf. No yellow-leaf was found on the vigorous-growing trees, while the slow-growing trees showed the most yellow-leaf. Neighboring trees showed variations in the amount of yellow-leaf ranging from zero to 20 per cent of the entire foliage of the tree.

Orchard 4.—This orchard was on a low, flat site and was given the two sprays for cherry maggot on June 12 and 27. No leaf-spot was in evidence, altho the check trees showed at least 30 per cent leaf-spot. Some of the trees showed a "staghead" in the top due to the dying of the smaller branches. On such non-vigorous trees the amount of yellow-leaf was as high as 60 per cent of the foliage, while the vigorous healthy trees nearby showed none.

Orchard 5.—The orchard was given an application of the fungicide on May 29 which was seven days after petal fall. Good commercial control of the leaf-spot was obtained by this single early application. However, the trees showed from 2 to 5 per cent of a recent infection of the leaf-spot fungus, and thruout the orchard about 0.5 per cent of yellow-leaf was observed. The vigorous trees were free from diseased leaves, while the slow-growing trees showed as high as 5 per cent of leaf-spot. Young, vigorous-growing trees, which were unsprayed and had a terminal growth of 12 to 18 inches, showed about 20 per cent of the leaves attacked by the leaf-spot organism.

Orchard 6.—This orchard was not in the experiment but was a continuation of Orchard 5 and was sprayed June 20 and July 9. It showed variations of from 10 to 70 per cent of the leaves infected with the leaf-spot fungus.

OBSERVATIONS IN OTHER ORCHARDS

Observations were made in numerous orchards in western New York to ascertain if there could be found a correlation between the amount of defoliation and the timeliness of the spray applications. Many orchardists, for sake of economy, omitted the pre-blossom and the petal fall applications. They intended to make the spray 10

days after petal fall but were delayed on account of rain. During that rain infection took place in some orchards. The writers applied a compromise spray which was made about midway between the petal fall and that usually made 10 days later. Other orchardists who were fortunate enough to have made a similar spray found that they were able to prevent leaf-spot infection until the time necessary for the first application for the control of the cherry fruit fly on June 12 to 15.

In the survey the writers often found anomalous conditions in which unsprayed and neglected orchards were entirely free from leaf-spot. On the other hand, orchards were found in which thoro spraying was practised, but not at the proper time. An analysis was made of the numerous factors which either together or alone influenced the defoliation of the trees. A brief summary of the factors involved are contained in the following observations:

1. Portions of an orchard situated on land receiving good soil and air drainage showed a tendency to have the least defoliation.
2. Defoliation may be caused by two distinct factors, *viz.*, fungous infection and a physiological disturbance in the leaf or tree.
3. Fungous infection of the leaves did not take place on the same day in all orchards.
4. Infection took place in some orchards 13 to 15 days after petal fall, while in most orchards it occurred 24 days after petal fall.
5. In most orchards applications of a fungicide made just prior to the heavy rain of June 14 held the leaf-spot fungus in check.
6. In a few orchards the primary infection took place during the rains of June 4, 5, and 6, so that sprays applied after that date did not check infection.
7. As judged by our sprayed plots, an application made seven to nine days after petal fall would have prevented infection.
8. Leaf-spot was most prevalent on the least vigorous trees.
9. In some orchards yellow-leaf and leaf-spot could readily be distinguished, while in others these types were hopelessly mixed so that classification was impossible.
10. Yellow-leaf was not influenced by the applications of fungicides.
11. Yellow-leaf was most abundant on trees growing in poorly drained locations.
12. Yellow-leaf was found on trees lacking vigor and growth.
13. Yellow-leaf was associated with trees suffering from winter injury of the roots.

OBSERVATIONS ON MORELLO

Observations made on the Morello indicated that the infection of the leaf-spot fungus (*C. hiemalis*) was quite general in the state and resembled a similar infection found in 1925. Spray applications were made at the same time that Montmorency was sprayed, and hence about the same amount of disease was present. Waves of infection continued so that newly formed leaves were badly diseased or defoliation took place by picking time.

SMALL CHERRY

It has been pointed out that there was great irregularity in the ripening of the Montmorency cherry, and that due to the season and the defoliation, the fruit on the innermost branches were undersize. It later enlarged and matured without shrinkage. Such fruit is not designated as small cherry. Small cherry was found to develop on the Morello about July 23 in sprayed and unsprayed orchards where the leaf-spot developed. Further light was cast on the underlying causes of small cherry. A similar outbreak of the leaf-spot was observed in 1925 and experiments (2) were conducted in 1926 to determine the cause of small cherry. It was found at that time that the excessive use of lead arsenate produced stem injury. No injury to the stems was observed on the checks, and it was evident that the lead arsenate when used alone produced a constriction of the stem and subsequent dropping of the fruit.

In 1928, the subject was again considered and it was found that stem injury was abundant in sprayed and unsprayed orchards. As no insecticide or fungicide was applied to one neglected orchard near Geneva, it was given special attention. It was found that the leaf-spot fungus was abundant on the stems, and it was readily determined by the presence of the acervuli and spores on the newly formed lesions as shown in Figs. 3 and 4. Similar infection was found in the

FIG. 4.—"SMALL CHERRY" OF MORELLO. Compare the normal fruit (right) with the fruit attacked by the shot-hole fungus (left). Many affected cherries dried on the trees before harvest time.

untimely sprayed orchards. No such infection was observed by one of the writers in his experiments of 1926. Hence, it is established that the fungus *Coccomyces hiemalis*, as well as the excessive use of lead arsenate, may induce a constriction of the stem which cuts off the sap flow and results in the production of small

FIG. 5.—CRACKING OF GREEN MORELLO CHERRIES DUE TO THE SCAB FUNGUS, *Cladosporium carpophi'um.*

cherry. Where infection is once established it appears reasonable to expect further injury about the lesion by the chemical action of the sprays.

SCAB

In the same unsprayed Morello orchard considerable infection of the scab organism (*Cladosporium carpophilum*) was observed. It is often associated with a disease of the peach where a dark spotting

with more or less cracking of the fruit results. This fungus must be considered as another causal agent of small cherry. On the green and yellow fruit olivaceous blotches may be seen spreading over the surface in a fine network. Later a russeting appears with more or less disintegration of the outer layer of tissue. Beneath the blotches the tissue fails to maintain its growth, resulting in the cracking of the fruit as shown in Fig. 5. On the ripened fruit the russeted blotches are conspicuous against the bright background of the normal tissue. It appears that excessive evaporation takes place thru such injured tissue, resulting in the production of small cherry.

RELATION OF DEFOLIATION TO VIGOR OF TREE

At the outset, the writers were impressed with the fact that all trees in an orchard usually did not suffer alike from defoliation. As shown in Fig. 1 it was common to see neighboring trees, one of which was vigorous and free from disease, while the other non-vigorous tree showed severe defoliation. Hence, at the time of maximum amount of yellowing of the foliage, the writers examined the test orchards as well as other commercial orchards to note the relation of defoliation to the vigor of the tree. In all cases neighboring trees were selected and comparable branches utilized in gathering the data. At first the number of diseased leaves on a branch were counted and the percentage of the foliage determined. Later it was an easy matter to estimate the amount of disease present on the tree and the amount that had fallen to the ground.

The vigor of the tree was ascertained by measuring the length of the yearly terminal growth of the branches. It was found that comparable branches on the same tree made similar terminal growth so that representative branches showed its history by means of the length between the annual scars. The relation of the disease present to the vigor of the tree is tabulated in Table 2.

In some orchards the trees have made no growth for several years, while in others the growth was normal until 1928. The following factors may be considered as influencing the rate of terminal growth.

EXCESSIVE CROPS

The production of a large crop may tend to reduce the apical growth. This did not enter in as one of the factors in 1928, for some of the orchards, as for instance orchard 7, had not produced a crop in

TABLE 2.—PERCENTAGE OF DISEASED CHERRY LEAVES IN RELATION TO THE YEARLY GROWTH OF THE TREE, JULY 3, 1928.

ORCHARD NO.	DATES OF SPRAYING	PERCENTAGE OF LEAF-SPOT	PERCENTAGE OF YELLOW-LEAF	YEARLY APICAL GROWTH OF BRANCHES IN INCHES							
				1928	1927	1926	1925	1924	1923	1922	1921
1	May 25 and	0	0	4	8	4	6	11	11	10	9
1	June 12	trace	0	10	6	4.5	6	10	11	8	6
2	June 12 and	0	0	5.5	3.5	2	2.5	5.2	8	14	12
2	28	0	0	0.2*	0.2	0.2	3	5	9	14	11
2		0	0	5	3	2	1	5	5.5	13	12
2		0	0	0.2	3	4	11	12	10	6	12
3	June 12	0	0	6	1	2	1.5	1	0.5	0.5	3
3		0	8	0.7	0.5	0.5	1.7	8	4	8	5
3		0	0	6	3.5	2	9	10	3.5	7	6
3		0	20	2	0.2	6	9	16	3.5	5	7
4	June 12 and	0	0	8	5.5	4	5.5	7	9	9	10
4	27	0	50	0.5	0.2	0.2	2.5	1.7	3	5	3
4		0	0	8	8	10	6.5	6	14	10	10
4		0	60	0.5	0.7	0.5	1.7	1	2.5	4	1.5
4		0	0	5.5	7	14	11	4	12	9	10
4		0	50	0.2	0.2	0.2	0.2	1	8	8	4
5	May 29 and	5	0.5	2.5	1	1	5	8	2	16	4
5	July 2	2	0	10	10	9	4	14	8	8	7
6		10	6	6	2.5	8	8	7	7	14	6
6	June 20	70	8	0.2	0.2	0.2	0.2	0.2	0.7	0.5	0.5

7	June 10 and	1	0	7	6	1.2	1.5	3.5	2	5	—
7	25	40	–	1	0.5	0.5	0.7	5	1	5	—
7		2	–	5	5	1.2	2	2	6	7	—
7		60	–	1	0.7	1	1.5	1.7	4	7.5	—
7		2†	–	8	12	6	7	4	4	3	2
7		80	–	0.2	0.2	0.2	0.2	0.2	1	2	6
8	June 8 and	2	–	5	6	6	5	1	4	7	15
8	25	28	–	0.5	0.2	0.2	0.2	1	5	8	10
8		3	–	4	3	5	7	5	10	10	14
8		30	–	0.5	0.5	0.2	0.5	4	5	4	8
8		2	–	5.5	4.5	1	5	9	6	10	12
8		30	–	1.5	1	0.5	1	3	1	0.2	10
8		0	85‡	1	14	16	8	10	2	—	—
8		20	–	6	13	13	6.5	12	6.5	—	—

*On July 23 leaves began to drop due to yellow-leaf.
†Tree shown in Fig. 7.
‡Tree shown in Fig. 6.

five years. In 1927 the fruit was so scattered that it was not profitable to harvest the crop. In orchard 3, on the other hand, there was a large crop in 1927 as well as in 1928.

LEAF-SPOT

The leaf-spot was of no economic importance in most orchards in 1926 and 1927. In a few cases the leaf-spot became prevalent at the end of the growing season. This was the case in orchard 3 in 1927. Hence the lack of growth on some trees in 1928 cannot be attributed to the residual effects of repeated defoliation due to the leaf-spot fungus.

LACK OF FERTILIZER

The lack of nitrogen in the soil did not enter into the consideration of this trouble, since orchard 7 has been treated repeatedly with applications of sodium nitrate without response. The same owner applied it to other orchards with excellent results. All factors were considered that might be the cause of the lack of growth, and it was clear that the real cause was injury to the root system by freezing.

WINTER INJURY OF CHERRY TREES

Commercial cherry orchards in 1928 indicated that defoliation was closely associated with the lack of vigor induced by winter injury of the roots. Winter injury may occur on the branches, or trunk, or roots. These types are briefly described as follows:

ON BRANCHES

During a severe winter the twigs and branches of the cherry may succumb to low temperature. It is not found every year, but may take place when low temperature is associated either with lack of maturity of the branches due to late growth or lack of nutrients brought about by excessive cropping and repeated defoliation. In 1917–18, trees, or even a single branch that produced heavy crops, showed severe injury while nonbearing trees were normal. This type of injury was not encountered in 1928.

ON TRUNKS

The trunk of a tree may show injury which may be either of a sun scald or open wound type. Splitting and rolling back the bark may be produced on any side of the tree, altho the southwest side suffers the most. Similar injury may be found in the crotches. It is usually

induced when the following conditions are correlated with a sudden drop in temperature, either in the late fall or early spring: 1. Severe pruning of the trees. 2. Warm weather either in early December or March. 3. Warm rains during this period followed by sudden low temperatures; the lower the temperature the greater was the degree of injury. This type of injury was not a factor in 1928.

ROOT INJURY

Root injury to sweet and sour cherry trees was common in 1928. Similar injury was reported in 1917 (10). It is present to a more or less degree in all orchards. Often it is unknown that the injury has occurred, since the signs are not always manifested.

The following stages indicate the nature and degree of injury that may occur in an orchard:

1. The trees may be killed without foliage appearing.
2. Trees may die at the time of blossoming.
3. Trees may produce foliage and then die at the first indication of dry, hot weather. At that time transpiration may exceed the water supplied by the roots. Wilting may take place during the day with slight recovery during the night. Due to the excessive rains in June, 1928, the effects of winter injury were not recognized until the hot days in early July.
4. Trees may die after one, two, or three years at any of the above stages. Trees may produce an abundance of fruit the first year with little terminal growth. Thereafter, the tree produces little growth and this sign is mistaken for the lack of growth due to overbearing. Staghead, or the presence of dead branches in the top of the tree, becomes apparent. A few trees succumb at the critical periods, while some outgrow the injury.

In 1928 all of the above types of root injury were present.

In Fig. 6 is shown a Montmorency tree that produced 14 inches of growth in 1927 and but 1 inch of growth in 1928. On July 14, the day the photograph was taken, most of the leaves had fallen, altho some green and limp leaves were present. In the background are trees that illustrate normal growth. In Fig. 7 is shown a tree with staghead which was produced by the dying of the branches in 1928. It was caused by the winter killing of the roots resulting from freezing during the winter of 1921–22. Since then, there has been a terminal growth of 4.25 inches and in the last five years the branches grew but 1.25

FIG. 6.—DEFOLIATION DUE TO WINTER KILLING OF THE ROOTS DURING THE MILD OPEN WINTER OF 1927–28.

Many trees did not show signs of injury until the first hot days in July.

inches. The trees have received applications of 3 pounds of sodium nitrate for the last three years without any stimulation of growth being observed.

CONDITION OF THE ROOTS

The relation of the rootstock to the susceptibility of the tree to winter injury no doubt entered into the problem under consideration. Formerly, nurserymen utilized Mahaleb stock because of its rapid early growth. It has been found by Howe (5) that longevity on

FIG. 7.—STAGHEAD OF CHERRY TREE DUE TO ROOT INJURY TRACED BACK TO THE WINTER OF 1921–22.

Mazzard is greater than that on Mahaleb. No doubt some of the older trees are on the latter stock which may account for the large amount of winter injury found in 1928. However, in orchard 3, trees were planted on both stocks but not much difference could be observed in their relation to winter injury.

In one of the orchards an examination of the roots was made in order to note the extent of winter injury. Trees were uprooted by

means of a tractor and carefully examined. In all cases the smaller and the feeding roots were blackened. Roots 1 and 2 inches in diameter were discolored at the cambium and the interior showed more or less blackening accompanied with the odor of fermented sap.

The tree in Fig. 8 was photographed July 14 and showed no discoloration in the larger root while the others clearly showed injury. As the roots approached the trunk they showed the least discoloration. In this case the injury occurred about eight years ago since the tree made but 9.27 inches of terminal growth in eight years.

FIG. 8.—THE LARGE ROOT AND TRUNK OF THE TREE WERE NORMAL, WHILE THE ROOTS UP TO 2 INCHES IN DIAMETER WERE WINTER KILLED. Injury followed severe pruning of lower branches. Photographed July 14, 1928

During the last two years it made a terminal growth of three-eighths inch. The orchard was about 25 years old and was surrounded by 20-year-old orchards that were normal and produced good crops. All received the usual application of sodium nitrate and response was noted everywhere except in the injured orchard. One could ascertain to a row from the foliage and the crop where the boundary between these two was located. They received similar treatment except that several years ago the injured orchard was given a severe pruning of the lower branches. Since then, the trees have gradually declined.

They have not borne a crop in the last five years, and in 1928 the fruit was scarce and widely distributed. These observations, substantiated by experimental data, clearly show the close relation between excessive pruning and winter injury that may take place under conditions conducive to injury.

HOW TO AVOID WINTER INJURY

At the outset it must be conceded that the subject of winter injury is complex and that often the factors involved are beyond the control of the fruit grower. Nevertheless, there are a few orchard practices that should be pointed out as influencing the susceptibility to injury. In the first place the trees should be propagated on the most hardy stock, and Howe (5) has found the Mazzard better than the Mahaleb. Even where all of the trees are on the same stock there appears to be a few in an orchard that are more hardy than others. This seems to be due to the individual variation in hardiness of the seedling used in propagation.

DRAINAGE

Usually, trees on the higher ground showed the least winter injury. However, elevation does not always signify good drainage. The tree shown in Fig. 6 was planted on a hillside where the previous trees also died from winter injury. At that place the water seeped from the hillside so that the land was wet for long periods after a rain. Where there is insufficient drainage the roots may make a late growth or they may suffer from lack of oxygen.

CULTIVATION

Some growers believe that there is less tendency toward winter injury where orchards are not thoroly cultivated. They allow the weeds to grow and make regular applications of sodium nitrate. The plow is being superseded by the tractor and the disc, and all necessary cultivation is mostly done by the latter. There appears to be good reason for not plowing in addition to the extra labor involved. In plowing, the soil is turned toward the tree in one year and away from it the next. During this interval some of the soil may be washed away from the tree so that at the second plowing the surface level has been lowered. The crown and roots are thus nearer the surface and subject to drought in summer and low temperature in winter. Under such a practice, winter injury most often takes

place since the roots do not possess a sufficient layer of soil to afford the best protection against low temperature.

PRUNING

The subject of pruning the cherry has been considered by Tukey (11) and hence will not be discussed here. There are numerous orchards in this State in which the trees have reached such a height that it is no longer possible to harvest the crop economically. Some of the trees are so close together that it is necessary to prune away the lower branches to permit passage of the spray outfit, as shown in Fig. 8. It would have been more satisfactory to have left the lower branches. In that case every other row should have been removed to permit proper expansion. Now, it is necessary to prune such high trees and it is difficult to advise just how far to cut back. Some have "dehorned" the trees with good results, while in other years the same method would have caused much winter killing of the trees. It appears more logical to extend the process gradually over a period of years so as to reduce the possibility of injury to a minimum.

Where staghead is present or where the trees are not vigorous due to apparent winter injury it may be worth while to prune back the tree judiciously so as to induce the production of new branches; and to make proper applications of sodium nitrate.

WILL PRESENT DEFOLIATION INDUCE WINTER INJURY?

It has been observed repeatedly that almost complete defoliation showed no effect on the following crop. This may be attributed to the early formation of the cherry buds that function the next year. If defoliation takes place late in the season or even in the month of September, little or no injurious effect was observed the following year. It is conceded, however, that the earlier complete defoliation takes place the greater will be the effect upon the stored nutrients. Should such defoliation take place repeatedly in successive years, its effect on the crop would ultimately be apparent.

Some investigators have found that after an attack of leaf-spot winter injury may be expected the following year. From our experience it does not always follow that such is the case. If the stored nutrients are low,a severe winter like that of 1917 -18 may cause

injury to the branches. Nevertheless, it is believed that many trees will succumb from winter injury in the next few years. In 1928, the winter injury preceded the defoliation found in many orchards. Sweet and sour cherry trees were dying in the early part of July at the time of the first hot weather. In some cases the injury was caused in the open and mild winter of 1927–28, while in others the initial injury could be traced back to 1922. If trees succumb during the winter of 1928–29 it may appear to be due to the defoliation of 1928, whereas, actually, the injury was initiated prior to infection by the leaf-spot fungus (*C. hiemalis*.)

DISCUSSION AND CONCLUSION

Since the prevalence of the cherry fruit fly has become general in this State, there has been a gradual modification in the time of the spray applications. Altho a definite spray schedule has been outlined, it has been found that many growers regularly omit certain of the recommended applications. Large pickings have been rejected in the past by canners because of the presence of the cherry maggot. The losses involved have forced all growers to recognize the fact that they cannot omit the two sprays necessary for the control of this insect. One of these applications is made at the time that Early Richmond shows red on one side, while the second is applied when Montmorency shows red on one side. In 1928, the dates of application for Geneva were approximately June 12 to 15 and again on June 25.

Some orchardists feel that they are not justified in making further applications. During 1926 and 1927, many growers have observed that the two maggot applications were sufficient to control the fruit fly and the light infection of leaf-spot. Many had a similar experience in 1928, especially where the orchard was favored by exposure of site, soil, air drainage, etc. Those not so fortunate found that dependence could not be placed entirely on these sprays alone since infection took place June 5 to 6. Hence it appears that economically it is a sound practice to make at least one additional application of a fungicide to prevent a possible infection of the leaf-spot fungus.

Conceding that a third application may be profitable insurance in some years, it is a matter for the grower to decide when that application should be made. Many are reluctant to make both the application at petal fall and the one 10 days later, since in the last

few years they have experienced no distinct advantage from spraying at petal fall. These orchardists may find it advisable to make but a single application which would fall between these two periods. Such a spray would be applied during the last days of May (for Geneva) or four to seven days after petal fall. Sufficient spray residue would be present to prevent infection by the leaf-spot organism until the time when the application for the control of the fruit fly is made. A few orchardists, however, will continue to apply both the petal fall spray and the one 10 days later so as to control the curculio and a possible early infection of the leaf-spot.

In 1928, many growers did not apply the preblossom and the petal-fall spray and could not apply the one 10 days later because of the continuous rains. Similar rains in other years were accompanied by an epiphytotic of the leaf-spot fungus. To prevent complete defoliation in 1928, an emergency application of a fungicide was made after picking in order to check the further spread of the fungus.

The defoliation of the cherry in 1928 was due partly to a physiological cause and partly to infection by the leaf-spot fungus (*C. hiemalis*). Both of these were most prevalent on the non-vigorous trees. This lack of vigor was not due to lack of cultivation and soil nutrients, but was the result of winter killing of the roots that occurred in the winter of 1927–28. Often the injury was traced to other years, even as far back as 1922. It is believed that within the next three years many cherry trees will gradually die from the result of recent winter killing and that such injury should not be attributed wholly to the defoliation that took place during 1928.

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